Chapter Six: Issues Related to Oil and Gas Exploration, Development, Production, and Transportation

Contents

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A. Geophysical Hazards

The primary geophysical hazards within the Copper River basin study area include earthquakes, faulting, volcanoes, permafrost and frozen-ground phenomena, and seasonal flooding and sediment hazards. These geophysical hazards could impose constraints to exploration, production, and transportation activities associated with possible petroleum development, and should be considered prior to any siting, design, or construction of facilities.

1. Earthquakes and Faulting

There are three major faults within the area of the Copper River basin: the West Fork, Taral, and Border Ranges (Figure 6.1). The West Fork and Taral Faults occur along the northern and eastern edges of the Copper River basin. These two faults are largely covered by surficial deposits, mainly glaciofluvial or glacial lake deposits. They generally trend east-west to southeast, with near vertical dips (Nokleberg et al., 1994).

Geophysical evidence for the West Fork Fault consists primarily of the major east-west striking Sourdough magnetic high that occurs along the fault. This magnetic high is interpreted as a near-vertical body of mafic or ultramafic rocks (rocks composed mainly of magnesian silicates) between the Peninsular terrane and the metamorphic complex of Gulkana River. The West Fork Fault trends southeastward and may connect with the Taral Fault underneath the unconsolidated Quaternary deposits of the Copper River basin (Nokleberg et al., 1994). The most recent movement along these two faults is reportedly in late Mesozoic or early Tertiary time.

The Border Ranges Fault is considered a former boundary between the subducted oceanic plate and the continental plate. This fault is buried by alluvial deposits of the Copper River basin, but is interpreted to occur just south of Tonsina in an arcuate nature, then crossing the Copper River with a northeast-southwest trend (Nokleberg et al., 1994). The fault plane generally dips between 70° to 90° at places where it outcrops at the surface in areas outside the study area. The most recent movement along this fault is reportedly in late Mesozoic or early Tertiary time. There is evidence in the Twin Peaks area of the western Chugach Mountains that the Border Ranges Fault may have had minor displacements since the Holocene time (10,000 years ago).

Geologic studies indicate that powerful earthquakes (magnitude 7.8 or greater) have occurred at least once every 525 to 700 years during the past 4,700 years in this area (Davies, 1985). Potentially damaging earthquakes (magnitude greater than 5.5) have occurred more frequently. Moderate earthquakes are not expected to cause much damage in the Copper River basin. However, strong earthquakes may cause localized rock falls in the surrounding uplands and liquefaction features within the unconsolidated deposits of the

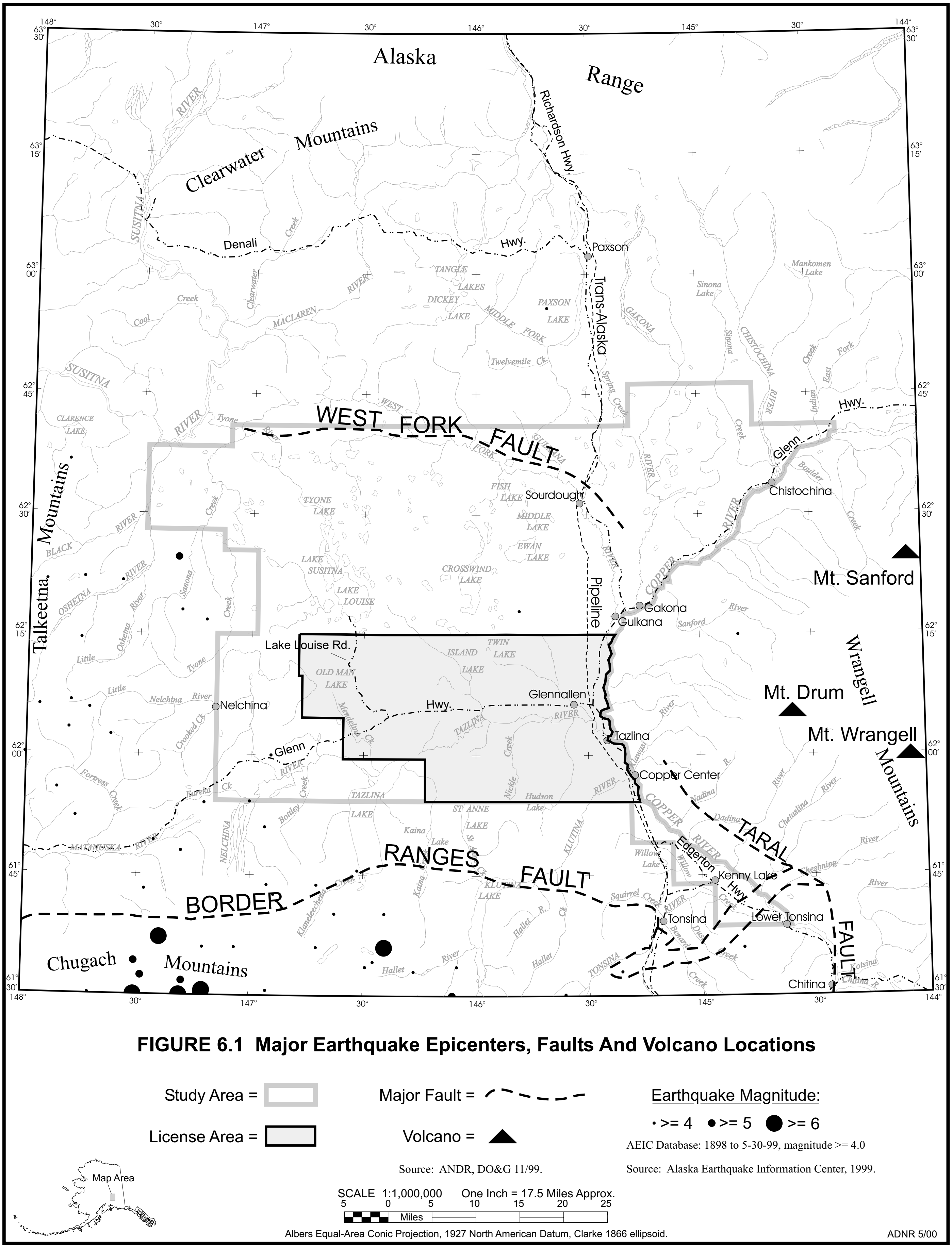

FIGURE 6.1 Major Earthquake Epicenters, Faults And Volcano Locations

Copper River basin. Other effects may include horizontal movement of vibration-mobilized soil, fissuring, and associated sand extrusions typical of areas where the ground surface is frozen.

There is a potential for severe earthquakes located outside the study area to impact the study area. The epicenter of the 1964 earthquake (moment magnitude 9.2) was in Prince William Sound. However, the impact of this earthquake was widespread, and moderate structural damage occurred in Glenallen, with disruption of power for more than 4 hours (Selkregg, 1974). Little additional information is available detailing the effects of the 1964 earthquake on the Copper River basin. This may be attributed to the relatively stable subsurface environment in this area, as well as the distance of the earthquake from the study area.

It is standard industry practice that facility siting, design, and construction be preceded by site-specific, high-resolution, shallow seismic surveys that reveal the location of potentially hazardous geologic faults.

The entire study area lies within seismic zone 4 of the Uniform Building Code (on a scale of 0 to 4, where 4 represents the highest earthquake hazard), and earthquake potential is relatively high. Structures in the study area should be built to meet or exceed the Uniform Building Code requirements for zone 4.

2. Volcanic Hazards

The Copper River basin may be affected by ash from the active volcanoes of the Cook Inlet region to the southwest. There are six volcanoes in this region that have erupted in Holocene time (10,000 years ago) (Miller and Richter, 1994). Three of these (Mt. Spurr, Mt. Redoubt, and Mt. St. Augustine) have erupted more than once this century and could erupt again in the future. During their periodic eruptions, the Cook Inlet stratovolcanoes produce abundant ash. There is a potential for ash generated during violent eruptions to impact the Copper River basin, depending on prevailing winds and other climatic conditions. Based on the distance of the study area from the Cook Inlet volcanoes, ashfalls originating from this source would be expected to accumulate only an eigth of an inch or less in thickness in the Copper River basin. This thickness could represent a hazard to airplane traffic and result in damage to mechanical and electronic equipment, such as engines and transformers, possibly causing engine failure or electrical shorting.

Mt. Wrangell is the youngest of three volcanoes just outside the study area (Figure 6.1). The other two volcanoes are Mt. Sanford and Mt. Drum, neither of which has shown any historic activity. Mt. Wrangell is a large andesitic (non-explosive) shield volcano located east of the Copper River Basin that exhibits a large fumarolic area near its summit and is the only volcano in the Wrangell volcanic field with reported historic activity. The last reported eruption was steam in 1966. Mt. Wrangell is indented by a 2.5- by 3.7-mile, ice-filled summit caldera. Three small (less than 0.6-mile) post-caldera craters, all geothermally active, lie along the west and north rims of the caldera. Mt. Wrangell's last major eruption was less than 1 million years ago (Miller and Richter, 1994).

Previous eruptions from these volcanoes appear to have been nonexplosive, with little potential to directly impact the study area. The primary hazard to the Copper River basin from the Wrangell volcanic field would be large volume lahars. Lahars are mudflows or landslides which can be generated by lava flows on the glaciated and snow-covered slopes of a mountain. Melting of the frozen material, mixed with ash, forms the lahars. These lahars have the potential to flow down the tributaries to the Copper River, resulting in flooding along the Copper River. Areas immediately adjacent to the Copper River could be the most heavily impacted.

Fortunately, such activity appears to be relatively rare in the study area. Many of the measures taken to prevent damage from seasonal flooding (Section 4) would be effective against lahars. These measures would include flood-frequency and river bank stability analyses, documentation of historic flood areas, and mapping of inactive river channels. Containment dikes and berms installed to reduce flood damage would also be effective against lahars.

3. Permafrost and Frozen Ground Phenomena

Permafrost is defined as soil, rock, or any other earth material whose temperature remains below freezing continuously for two or more years. Most of the permafrost in Alaska has been in existence for many thousands of years. The presence of permafrost depends upon the glacial and climatic history, the thermal properties of the local sediment and rock, and the insulating properties and thermal balance of material at the ground surface. The factors that control the distribution of permafrost also control its temperature, which varies markedly with depth, latitude, and geologic and topographic setting. Large, deep bodies of water (rivers, lakes, and oceans) also affect soil temperatures.

During the winter months, thermal contraction of the ground surface may cause it to crack in a pattern resembling mud cracks, only much larger. Summer meltwater pours into these cracks in the permafrost and freezes, forming a vertical network of intersecting ice veins. Repeated cracking at points of weakness causes these veins to grow into a network of massive ice wedges, which are sometimes indicated by polygonal-shaped ground surface markings. Some ice wedges are the products of ancient climates that are preserved in permafrost at considerable depths.

The Copper River basin is characterized by moderately thick to thin permafrost in areas of fine-grained deposits, and by discontinuous or isolated masses of permafrost in areas of coarse-grained deposits (Ferrians, 1994). Engineering modifications of the environment can cause thawing of permafrost in two ways. The first is by changing the seasonal thermal balance at the surface, which can be caused by gravel pads, damage to the organic surface layer, or disrupted surface drainage. The second type of modification results from heated buildings or uninsulated buried pipelines conveying material at temperatures warmer than the surrounding soil. The primary engineering problems resulting from thawing of permafrost relate to its potential loss of strength and volume. This can cause severe differential settlement or loss of bearing strength, which would affect roads, pads, and foundations.

Site-specific geotechnical studies should be conducted prior to any development activities to assess the local permafrost conditions, so the most cost-effective engineering modifications can be included during the design phase of the planned development. Permafrost problems can be mitigated through proper siting, design, and construction considerations. Structures, such as drill rigs and permanent facility buildings, should be insulated to prevent heat loss into the substrate. Pipelines can be trenched, backfilled, insulated (if buried), or elevated to prevent undesirable thawing of permafrost.

4. Seasonal Flooding and Sediment Hazards

The Copper River basin is a relatively smooth plain, 1,000 to 2,000 feet in altitude, cut by the Copper River and its tributaries. The Copper River and most of its tributaries start from glaciers in the surrounding mountains and have braided courses. Large lakes occupy deep basins in the mountain fronts, and thaw lakes are abundant on the eastern plain of the basin.

Floods in this area could be caused by several different mechanisms. Glacially-dammed lakes can be released suddenly, causing large floods. Ice jam flooding might add to the flood hazards in the Copper River basin. Excessive rainfall can also cause seasonal flooding in the region. The following paragraphs describe these mechanisms, and their potential impact on the study area.

Glacial outburst occurs when glacial movement opens a pathway for water to escape. The Copper and Gulkana Rivers, and their tributaries, are subject to glacial outburst floods as a result of the sudden drainage of large, glacier-dammed lakes. Dammed lakes backed up by the Nelchina Glacier have, in the past, broken out and produced large flood crests in the Tazlina Valley.

Ice jam flooding occurs during breakup when ice blocks a river or stream, in effect becoming a dam. This causes water to back up and flood the adjacent land. Ice jam flooding is localized, but affects the greatest number of residents over time because of the high population concentration along rivers.

The least frequent cause of flood hazard in the Copper River basin is excessive rainfall. The result of unusual combinations of extreme meteorological conditions and snowmelt may cause the rare occurrence of flooding in the region. Unusual conditions may include: the interaction of tropical moisture with a deep, low pressure system; blockage of the eastward movement of this tropical low by a high pressure ridge in eastern Alaska and/or western Canada; saturated soil conditions; and greater than normal glacial melt due to preceding storms. In addition, excess sediment deposition in channels due to rapid runoff might decrease the carrying capacity of the streams.

Seasonal flooding of lowlands and river channels is extensive along the major rivers that drain into the Copper River basin study area. Thus, measures must be taken prior to facility construction and field development to prevent losses and environmental damage. Pre-development planning should include surveys of spring break-up activity, as well as flood-frequency analyses. Erosion rates, sediment grain-size and cohesiveness, and river bank stability must also be considered in determining facility siting, design, construction, and operation. Structural failure can be avoided by proper facility setbacks from rivers and main tributaries.

As part of predevelopment planning, data should be collected on water levels, ice floe direction and thickness, discharge volume and velocity, and suspended and bedload sediment measurements for analysis. Also, historical flooding observations should be incorporated into a geophysical hazard risk assessment. Inactive channels of a river must be analyzed for their potential for reflooding. Containment dikes and berms might be necessary to reduce the risk of floodwaters that might undermine facility integrity.

B. Likely Methods of Transportation

The location and nature of oil or gas deposits determine the type and extent of facilities necessary to develop and transport the resource. Strategies used to transport potential petroleum resources depend on many factors, most of which are unique to an individual discovery. The following is a general discussion of the components that might be in any transportation system.

1. Pipelines

Pipelines are the only economically feasible way to transport oil and gas onshore. Transportation by truck is not economically feasible, because of the low quantities of oil that can be moved this way and high labor costs. The Trans-Alaska Pipeline System (TAPS) crosses the study area, generally following the Richardson Highway. The most likely method of transportation would involve building feeder lines to TAPS and transporting oil to Valdez for shipment. TAPS represents the only existing infrastructure; all feeder lines would be new construction. TAPS can throughput up to 2.2 million bbl per day. However due to declining production on the North Slope the current average thoroughput is approximately one million bbl per day (Alyeska Pipeline, 1999). Therefore, TAPS could likely absorb any production from the study area.

If sufficient natural gas reserves are discovered and it is economically feasible, the gas could be made available to local communities through new pipelines. Gas may also be re-injected, as is done on the North Slope. A future pipeline or other method of bringing North Slope gas to market may make it possible to market gas from the study area beyond local communities.

Pipelines will be either elevated or buried depending on local soil conditions and other considerations such as movement of wildlife. An individual pipeline may alternate between buried and elevated, as is the case with TAPS.

a. Elevated Pipelines

Elevated pipelines are typically used in Alaska to prevent heat transfer from the hot oil in the pipeline to frozen soils, since heat would degrade the permafrost. Elevated pipelines are easy to maintain and visually inspect for leaks. However, above-ground pipelines can restrict caribou and other wildlife movements unless provisions are made to allow for their safe passage.

There appears to be a cumulative effect of roads and adjacent pipelines that creates a barrier to caribou crossing. Pipelines elevated a minimum of five feet have been shown to be effective except when they were in proximity to roads having moderate to heavy traffic (15 or more vehicles/hour). Roads with low levels of traffic and no adjacent parallel pipeline are not significant barriers to movement of caribou. In areas where pipelines must be placed above ground, pipelines must be sited, designed, and constructed to allow free movement of moose and caribou.

b. Buried Pipelines

Buried pipelines are feasible as long as the integrity of the frozen soils is maintained. There are some important considerations regarding long sections of buried pipe. First is cost, which depends on length, topography, soils, and distance from the gravel mine site to the pipeline. Second, buried pipe is more difficult to monitor and maintain. However, significant technological advances in leak detection systems have been made, which increase the ease with which buried pipelines can be monitored. These systems are described below. Third, buried pipelines may involve increased loss of wetlands because of gravel fill. Finally, buried pipelines are sometimes not feasible from an engineering standpoint because of the thermal stability of fill and underlying substrate (Cronin et al., 1994:10).

2. Oil Spill Risk

Any time crude oil or petroleum products are handled there is a risk that a spill will occur. Oil spills associated with exploration, development, production, storage, and transportation of crude oil may occur from well incidents (blowouts), pipeline spills, tanker spills, and chronic operational spills of low volumes involving fuels and other petroleum products associated with normal operation of drilling rigs, vessels and other facilities.

MMS has performed a quantitative oil spill analysis for North Slope onshore oil and gas exploration and development spills. While direct comparisons cannot be made with the Copper River basin, the North Slope experience may be useful in estimating likelihood of spills in the study area. The pattern of crude-oil spills that occurred on the North Slope is one of numerous small spills. Thirty-two percent of crude oil spills that occurred between 1989 and 1996 were less than or equal to 2 gallons. Fifty-six percent were less than or equal to 5 gallons. During that time period, no spill greater than 1,000 bbl occurred. The database spill size ranged from greater than 1 gallon to 925 bbl. The average crude oil spill is 3.8 bbl, and the median spill size is 7 gallons. The estimated crude oil spill rate for the North Slope is 199 spills per billion bbl produced (MMS, 1997:IV-A-31).

This information shows that most spills associated with exploration or production facilities are normally quite small, 5 bbl (210 gal) or less, and are usually related to everyday operations. Even a worst case oil discharge from an exploration facility, production facility, or pipeline is restricted by the maximum storage capacity or the well's ability to produce oil. For example, a well with a maximum production rate of 2,500 bbl per day will only spill a maximum of 2,500 bbl per day (Powers, MMS 1989:2). As another example, a 14-inch pipeline can store approximately 1,000 bbl of oil per mile of pipeline length. Accordingly, under static conditions if oil were lost from a five mile stretch of pipeline (a hypothetical distance or spacing between emergency block valves), then a maximum of 5,000 bbl of oil is all that would be discharged into the environment.

The state has enacted stringent oil spill prevention, control, and cleanup legislation (AS 46.04.010-900). The statute requires oil spill contingency plans which include methods for detecting, responding to, and controlling blowouts; prevention, control, and cleanup plans; and location and identification of cleanup equipment.

The risks associated with producing and transporting oil can never be reduced to zero. There is always some chance that spills will result from exploration, production, storage, and transportation of oil. However, the state's goal is to reduce the possibilities of spills to a level of acceptable risk and to improve the ability to respond to spills when they happen.

The stationary nature of North Slope exploration and production facilities and the predictability of maximum spill rates simplifies the development and implementation of oil spill contingency plans for those facilities. Even TAPS, with the tremendous quantities of oil flowing through that system, is designed to quickly shut down in the event of a rapid decrease in pressure such as would happen if there was a major break in the line. This safety feature, and many others, such daily visual monitoring and block valves along the entire pipeline, limit the volume of a spill. In contrast, the locations of tanker accidents are unpredictable and can result in millions of gallons of oil being discharged in a matter of hours.

3. Leak Detection

The technology for monitoring pipelines is continually improving. A number of leak detection systems are already in use or proposed for Alaska oil and gas pipeline development. Elements of these systems could be incorporated into any new pipelines constructed in the study area. Leak detection systems and effective emergency shut-down equipment and procedures are essential in preventing discharges of oil from any pipeline which might be constructed in the study area. Once a leak is detected, valves at both ends of the pipeline, as well as intermediate block valves, can be manually or remotely closed to limit the amount of discharge. The number and spacing of the block valves along the pipeline will depend on the size of the pipeline and the expected throughput rate (Nessim and Jordan, 1986:68). Industry on the North Slope currently uses the volume balancing method to determine this rate which involves comparing input volume to output volume.

Leak detection methods include acoustic monitoring, pressure point analysis, and combinations of some or all of the different methods (Yoon, Mensik, and Luk 1988). The approximate location of a leak can be determined from the sensors along the pipeline. A computer network is used to monitor the sensors and signal any abnormal responses. In recent years, computer-based leak detection through a Real-Time Transient Model has come into use. This technology can minimize spills from both new and old pipelines (Yoon and Mensik, 1988).

A similar technology for detecting leaks in oil and gas pipelines is termed Pressure Point Analysis (PPA). The method uses measured changes in the pressure and velocity of the fluid flowing in a pipeline to detect and locate leaks. PPA has successfully detected holes as small as 1/8-inch in diameter within a few seconds to a few minutes following a rupture (Farmer, 1989:23). Automated leak detection systems such as PPA operate 24 hours per day and can be installed at remote sites. Information from the sensors can be transmitted by radio, microwave, or over a hard wire system.

For TAPS, Alyeska employs three systems which can detect leaks down to 0.12 percent of rated capacity (100 bbl per hour). These include Line Volume Balance, Deviation Alarms, and Transient Volume Balance.

a. Line Volume Balance

LVB checks the oil volume in the pipeline every 30 minutes. The system compares the volume entering the line with the volume leaving the line, adjusting for temperature, pressure, pump station tank-level changes, and slackline conditions.

b. Deviation Alarms

There are three types of deviation alarms: pressure, flow, and flow rate balance. Pressure alarms are triggered if the pressure at the suction or discharge of any pump station deviates beyond a certain amount. Flow alarms are triggered if the amount of oil entering a pump station varies too much from one check time to the next. Flow rate balance alarms are triggered if the amount of oil leaving one pump station varies too much from the amount entering the next pump station downstream. This calculation is performed on each pipeline section about six times a minute.

c. Transient Volume Balance

TVB can both detect whether a leak may be occurring and identify the probable leak location by segment, especially with larger leaks. While the LVB leak detection system monitors the entire pipeline, the TVB system individually monitors each segment between pump stations. Since the TVB indicates in which area a leak may be occurring, focused reconnaissance and earlier response mobilization are possible (Alyeska Pipeline, 1999a).

d. LEOS

Another detection system which is available is LEOS (Leck Erkennung und Ortangs System), a leak detection and location system manufactured by Siemens AG. The system has been in use for 21 years and in over thirty applications.

LEOS consists of a three-layer gas-sensor tube that is laid next to the pipeline. The inner layer is a perforated gas transport tube of modified PVC. A diffusion layer of EVA surrounds and allows gasses to enter the inner tube. A protective layer of braided plastic strips forms the outer layer. The tube is filled with fresh air, and the air is evacuated through a leak detector at regular intervals. If leak occurs, hydrocarbon gasses associated with the leak enter the tube and are carried to the gas detector. The system is totally computer controlled, self-checking and re-setting. Background gasses are calibrated at setup and checked regularly. The system will pick up previous contamination and organic decomposition. The location of the leak is determined by monitoring the time that leaked gas arrives at the detection device.

The system is very low maintenance and will last the life of the pipeline. Special protective adaptations will be made for the cold temperatures in which the system will operate and for the backfill installation method that will be used to install the pipeline. The tube will be placed in a protective cover, and the system will be tested continuously as the segments are installed. LEOS will be strapped to the oil pipeline next to the poly spacers that will separate the gas line from the oil line. The system will detect leaks from both lines, and operators will be able to tell the difference between the two. Engineers estimate that it will take about 5 to 6 hours for leaked molecules to migrate to the LEOS tube. The air inside the tube will be evacuated and tested every 24 hours

e. Smart Pigs

Design and use of "smart pigs," data collection devices that are run through the pipeline while it is in operation, has greatly enhanced the ability of a pipeline operator to detect internal and external corrosion and differential pipe settlement in pipelines. These pigs can be sent through the pipeline on a regular schedule to detect changes over time and give advance warning of any potential problems. The TAPS operation has pioneered this effort for Arctic pipelines. The technique is now available for use worldwide and represents a major tool for use in preventing pipeline failures.

f. FLIR

ARCO Alaska has implemented a comprehensive FLIR (Forward Looking InfraRed) pipeline monitoring program in the Kuparuk oil field to assist in detecting pipeline leaks and corrosion. InfraRed sensors have the ability to sense heat differentials. Since Kuparuk oil flows from the ground at temperatures in excess of 100°F, a leak shows up as a "hot spot" in a FLIR video. In addition, water-soaked insulation surrounding a pipeline is visible because of the heat transfer from the hot oil to the water in the insulation and finally to the exterior surface of the pipeline. FLIR is effective 80 percent of the time in discovering water-soaked insulation areas that have produced corrosion on the exterior wall of the pipeline (ARCO, 1998).

FLIR also has applications in spill response and was used to image spills at both Prudhoe Bay and Kuparuk. The video frames were processed and registered into a GIS map database. The map database with the overlaid picture of the spill site was then used to quickly and accurately determine the area of the spill. This action allowed swift and accurate reporting of the spill parameters to the appropriate agencies. The video footage of the spill area allowed the incident command team to receive near real-time information in IR and color. This information permitted timely decisions to be made and the results of those decisions to be reviewed with the subsequent fly-over zone site. Various agencies involved in the process were able to see and verify the results of the cleanup process (ARCO, 1998).

To insure safe operation, pipeline operators would follow the appropriate American Petroleum Institute recommended practices. They would inspect the pipelines regularly to determine if any damage was occurring and would also perform preventative maintenance. Preventive maintenance includes installing improved cathodic protection, using corrosion inhibitors and continuing regular visual inspections.

No oil or gas may be transported from leases until the operator has obtained the necessary permits and authorizations from federal, state, and local governments. ADNR and other state, federal, and local agencies will review the specific transportation system when it is actually proposed.

Mitigation Measures

- Oil Spill Prevention and Control -- Lessees are advised they must prepare contingency plans addressing prevention, detection, and cleanup of oil spills. Lining, diking and buffer zones are required to separate oil storage facilities from marine and freshwater supplies.

- Wherever possible, onshore pipelines must utilize existing transportation corridors and be buried where soil and geophysical conditions permit. In areas where pipelines must be placed above ground, pipelines must be sited, designed, and constructed to allow free movement of moose and caribou.

- Pipelines must be located upslope of roadways and construction pads and must be designed to facilitate the containment and cleanup of spilled hydrocarbons. Pipelines, flowlines, and gathering lines must be designed and constructed to assure integrity against climatic conditions and other geophysical hazards.

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